The Sunset Solution: new possibilities for measuring C_L

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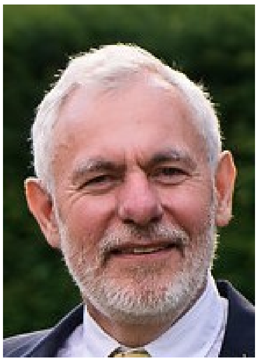
Thursday, February 9, 2023, 9 a.m. Central Time



Anthony Peirce is a Professor in the Department of Mathematics at the University of British Columbia, Canada. His presentation will be at 9:00 Central Time on Thursday, February 9, 2023. The topic is **“The Sunset Solution: new possibilities for measuring C_L.”**

Abstract

Current pressure decline analysis [1] is based on a model that assumes that the fracture footprint of a deflating hydraulic fracture remains the same as it was at the point of shut-in. However, laboratory and numerical experiments demonstrate that a hydraulic fracture in a permeable medium can, depending on the regime of propagation at shut-in, propagate beyond the shut-in footprint or start to recede almost immediately. While propagating hydraulic fractures have been subjected to significant theoretical and numerical study, the recession of hydraulic fractures has been investigated very little.

Motivated by the dearth of theoretical results for receding hydraulic fractures we have undertaken a detailed multiscale asymptotic analysis of the tip behaviour of a hydraulic fracture in a permeable elastic medium during the transition from arrest to recession [2] (the subject of Emmanuel Detournay’s talk in this series on the 26th January). These asymptotic results have enabled us to develop a rigorous numerical scheme to model the transition from arrest to recession. Significantly, after arrest and during recession, this analysis only assumes that the leak-off velocity is a regular function of space and time and is agnostic as to the detailed form of this function. Experiments with this recession-enabled numerical scheme establish the emergence of a self-similar solution as the hydraulic fracture approaches collapse [3,4].

This so-called Sunset Solution, which is caused by a fundamental decoupling of kinematics from dynamics reduces the governing equations to a simple kinematic condition that relates the rate of decrease in the fracture aperture and radius to the leak-off velocity. As a result of this decoupling, the Sunset Solution only depends on the Carter leak-off coefficient C_L – and is independent of the other three fundamental material parameters that also typically determine the evolution of a hydraulic fracture, namely, the plane strain modulus, the fluid viscosity, and the fracture toughness. Since the Sunset Solution isolates the leak-off coefficient C_L, it opens the possibility of estimating CL from laboratory or fields measurements of the declining fracture aperture.

In this talk we will briefly outline the derivation of the Sunset Solution [5] and provide compelling numerical evidence of its eventual emergence even after the fracture has undergone significant symmetry-breaking geometric changes. This ubiquity as an eventual asymptotic solution, even in complex hydro-mechanical environments, indicates that the Sunset Solution holds significant promise as a novel way to measure C_L. The challenge for us is to develop the capacity to measure the declining fracture aperture [6].

References

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[3] A. Peirce and E. Detournay, The arrest and recession dynamics of a deflating hydraulic fracture in a permeable elastic medium in a state of plane strain. Int. J. Solids Struct., 254-255, 111906 (https://doi.org/10.1016/j.ijsolstr.2022.111906), 2022.

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[6] Guglielmi, Yves, Mark McClure, Jeffrey Burghardt, Joseph P. Morris, Thomas Doe, Pengcheng Fu, Hunter Knox, Vince Vermeul, Tim Kneafsey, and The EGS Collab Team. 2022. Estimating Stress from Fracture Injection Tests: Comparing Pressure Transient Interpretations with In-Situ Strain Measurements. Paper presented at the Stanford Geothermal Workshop.

Biography

Anthony Peirce is a Professor in the Department of Mathematics at the University of British Columbia, Canada. During his PhD work as a Fulbright Scholar at Princeton University, he pioneered work on the optimal control of quantum molecular systems. Prior to his PhD, he worked as an applied mathematician at the Chamber of Mines Research Laboratories in South Africa, where he investigated rock fracture processes. His research contributions, along with collaborators, in hydraulic fracture modeling include the development of: the Implicit Level Set Algorithm (ILSA), which enables the use of multiscale tip asymptotics to accurately represent the fracture width on a coarse mesh and locate the fracture free boundary; the EKF-ILSA code, deployed under license by the CSIRO, which uses tiltmeter measurements to monitor the growth of hydraulic fractures in mines; a proppant model able to capture Poiseuille to Darcy flow and proppant packing; and an accurate technique to capture multiple elastic layers in the Planar3D Simulator using the Fourier Transform. He has published extensively on his research and has two US Patents. Further details are available on his website: www.math.ubc.ca/~peirce.